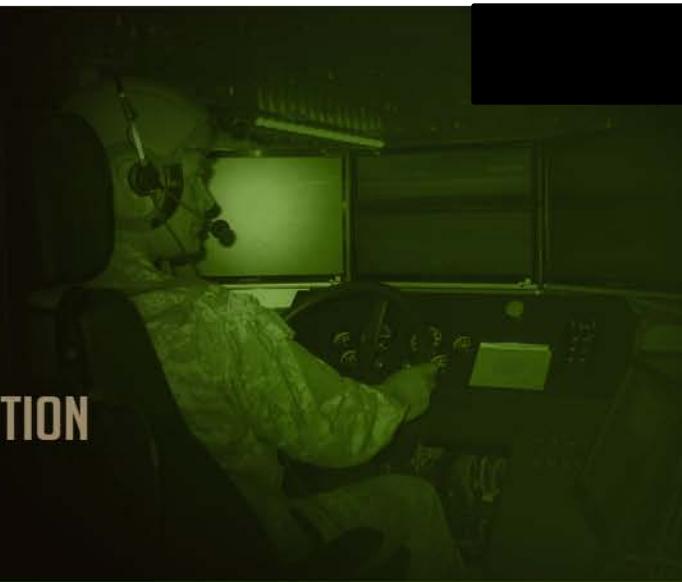




MSTV

MODELING AND SIMULATION, TESTING AND VALIDATION



SCALABLE POWER-COMPONENT MODELS FOR CONCEPT TESTING

Michael S. Mazzola, G. Marshall Molen, Stephen Phillips, Matthew Young, Charles Bilberry, Angela Card, and James Gafford
Center for Advanced Vehicular Systems (CAVS), Mississippi State University

Denise Kramer and Michael Pozolo
CASSI Analytics, Powertrain Modeling & Simulation, US Army RDECOM TARDEC

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Outline

- Motivation and Scope
- Integrated Starter Generator Model
- Battery Model
- Power Converter Model
- Summary





Motivation and Scope

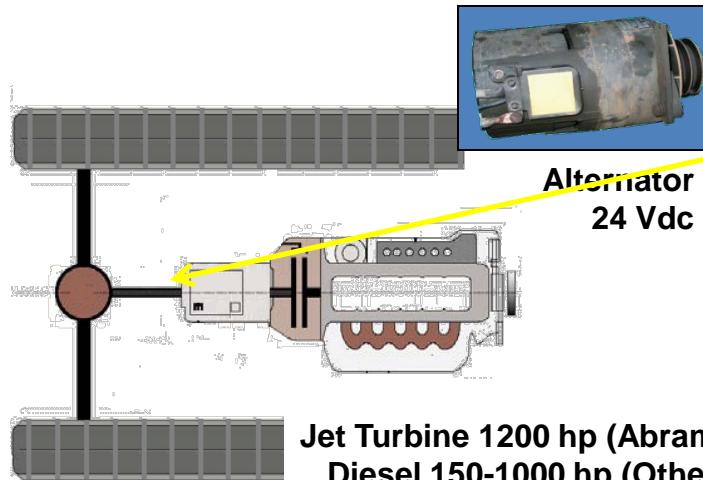


- **Objective:** Support modeling and simulation needs for rapid concept analysis and systems engineering.
- **Scope:** Scalable, generic MATLAB/Simulink models in three areas:
 - Electromechanical machines (Integrated Starter Generators)
 - Energy storage (Batteries)
 - Power conditioning (Converters)
- **Challenges:**
 - Creating generic, scalable models of “appropriate fidelity”
 - Providing diversity of technologies and ratings while managing fidelity
- **Importance to the Warfighter:** Providing more electrical power for loads ranging from C⁴ISR to anti-IED to soldier “hotel.” Improving fuel efficiency through electrification produces a stronger force through reduced logistics requirements.
 - Planning for future ground vehicle systems, whether legacy or new, is essential
 - M&S is cost effective tool for concept evaluations

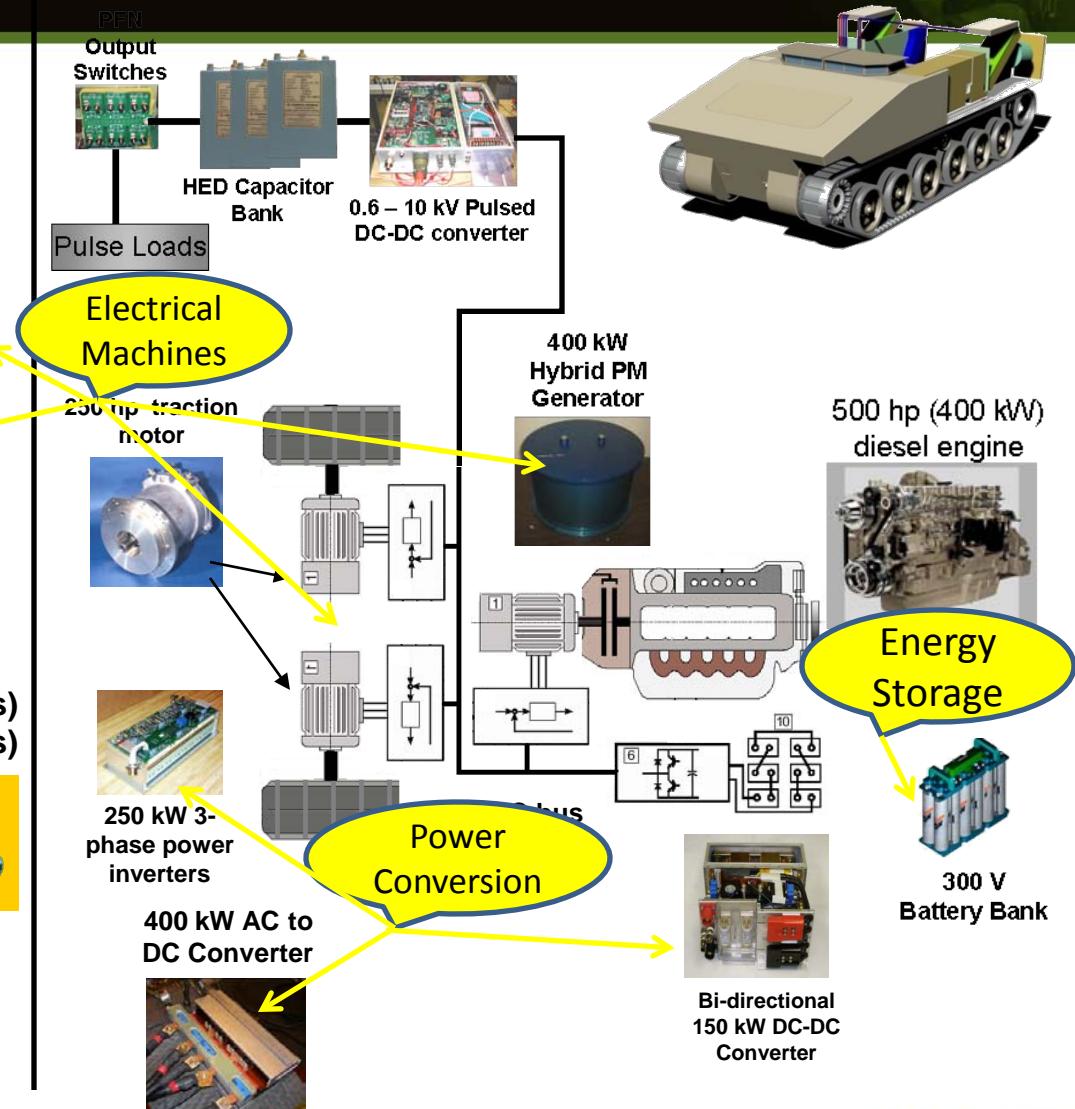
Legacy & Future Army Vehicles

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**Jet Turbine 1200 hp (Abrams)
Diesel 150-1000 hp (Others)**





ISG Model



- ISG model and its associated controls system
 - Automatic scaling
 - Scope of machines relevant to modern and legacy vehicles
 - Power levels between 4-110 kW
- Features
 - Coupled electrical and thermal models
 - Simulation driven scaling
- Use available machines to validate model
 - UQM Power Phase 75



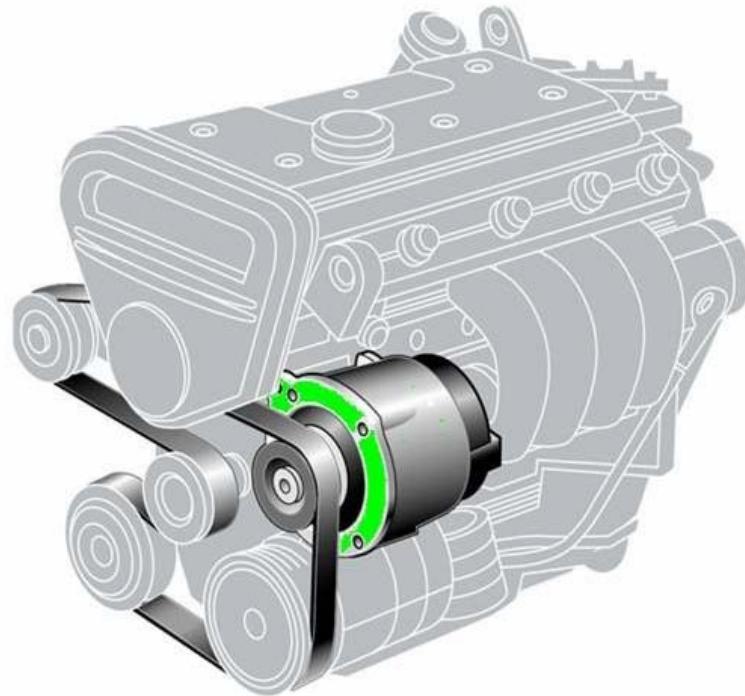
Types of ISG's

- **Internally Integrated ISG**
 - Machine that is integrated into the driveline of the vehicle
 - Scalable to power levels in 40-110 kW range
 - Examples:
 - GM Silverado – 7 kW system
 - DRS HMMWV – 30 kW system

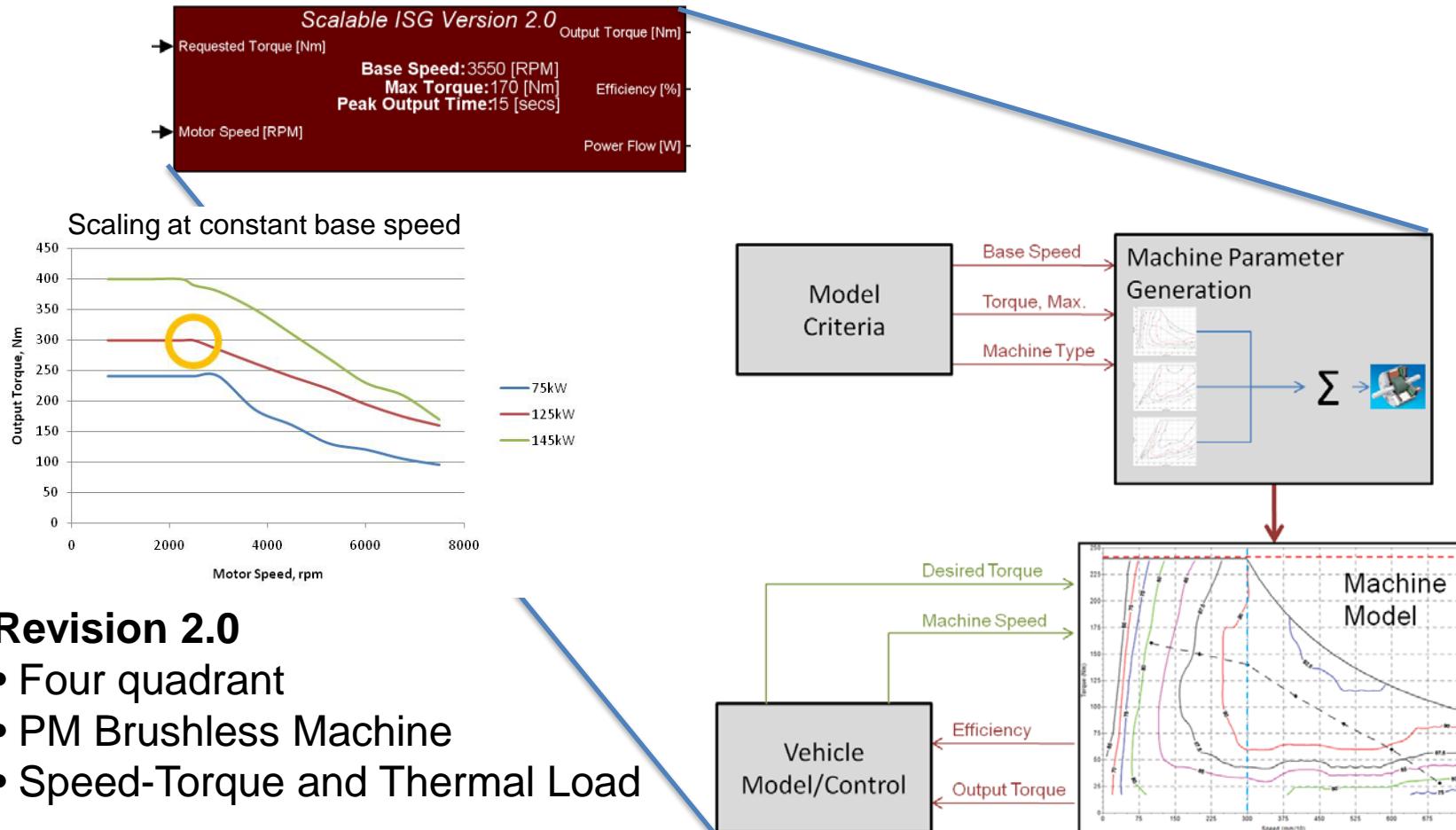


Types of ISG's

- **Externally Integrated ISG**
 - External machine that attaches to standard driveline
 - Power levels limited to components (i.e. belts) that attach the system to the standard driveline
 - Example: BAS System – 3 kW system



ISG Block, Rev. 2.0





- Battery model including charge storage and dynamic impedance

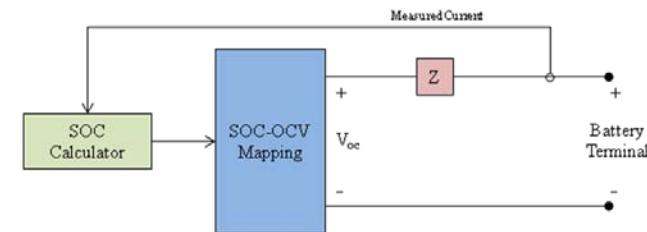
- Independent of chemistry
 - Scale parameters, not complexity
 - Energy levels between 0.2-20 kWh

- **Features**

- Polynomial-based state-of-charge to open-circuit voltage model
 - State-variable dynamic impedance model
 - Easy provision for lifetime and reliability model

- Use available batteries to validate model

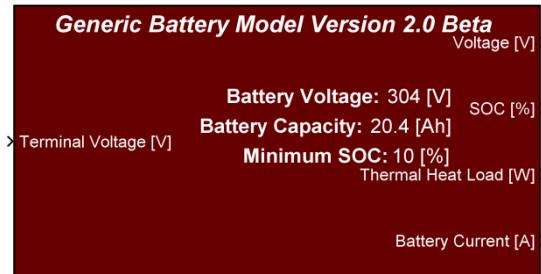
- UBBL10, 0.1 kWh, 16 V, LCO
 - A123, 21 kWh, 360 V, LPO
 - Prius, 1.3 kWh, 200 V, NiMH



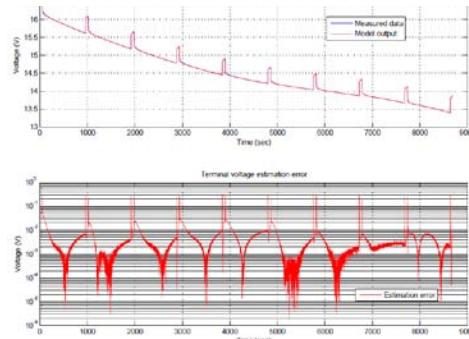
Battery Block, Rev. 2.0

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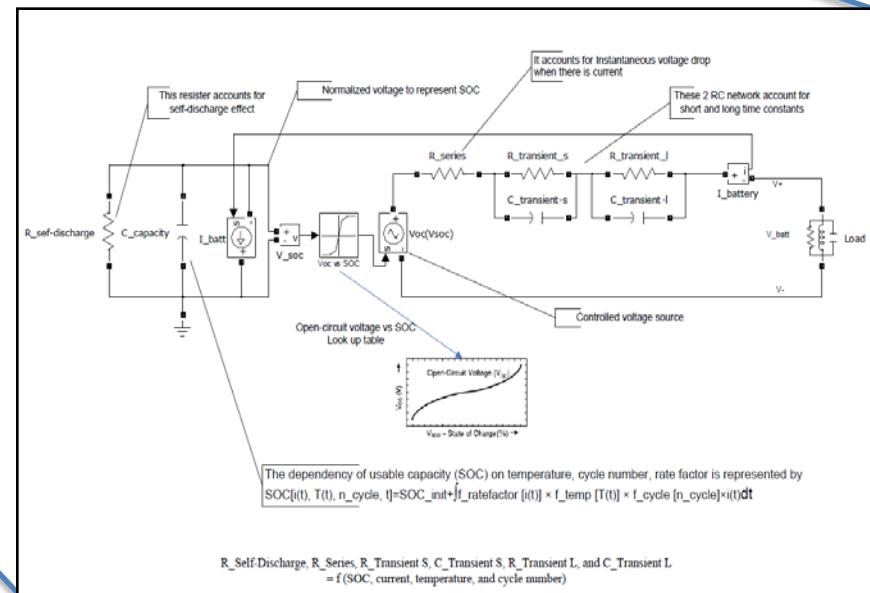


Approximation by Method of Bandwidth Limited Parameter Estimation



Revision 2.0

- Scale by capacity and voltage
- Select by chemistry
- Charge-counting or Self-consistent

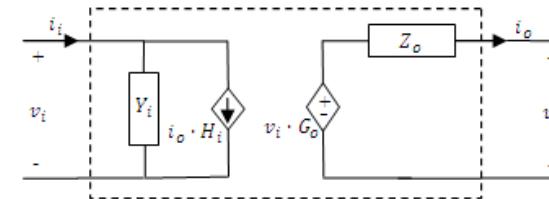


GVSETS

Converter Model



- Converter model including averaged electrical & thermal response
 - Large signal and small signal effects
 - Scale parameters, not complexity
 - Power levels between 5-110 kW
- Features
 - System description at terminals
 - Closed-loop control response embedded
- Use available converters to validate model
 - Absopulse, 7-kW, 300-V to 28-V, dc/dc
 - UQM 100-kW, 300-V, dc/ac





Summary



- Developed ISG and Battery beta models in Simulink.
 - Scalable ISG Ver. 2.0
 - Technology: Permanent Magnet Brushless DC machine
 - Model: Self-generating torque-speed-efficiency map
 - Future improvements: Induction machine
 - Scalable Battery Ver. 2.0
 - Technology: Lithium-Ion
 - Lithium-Cobalt-Oxide LiCoO_2
 - Lithium-Iron-Phosphate LiFePO_4
 - Model: Electrical Analogue, bandwidth-limited approximation
 - Charge-counting mode
 - Self-consistent mode
 - Future improvements: NiMH, LiMn_2O_4 (spinel), Lead Acid
- Near-term Future work
 - Scalable Converter Ver. 1.0
 - Technology: Semiconductor switched, DSP controlled dc/dc or dc/ac (TBD)
 - Model: Black-box averaged